AD NUMBER
AD102038
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TO: unclassified
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AUTHORITY
30 Nov 1967, DoDD 5200.10; APG D/A ltr, 19 Nov 1980

DSC-SA

ORDBG-1327--24 Oct

ARMOR TEST REPORT AD-1215

Aberdeen Proving Ground
MARYLAND

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STUDY OF IGNITION OF GASOLINE BY STATICALLY DETONATED 3.5" HEAT M28A2 ROCKET HEADS (U)

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D. A. PROJECT NO. 503-04-004

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Tenth Report TB3-1224B

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STUDY OF IGNITION OF GASOLINE BY STATICALLY DETONATED 3.5" HEAT M28A2 ROCKET HEADS (U)

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MARYLAND

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DA Priority: 1A

1 November 1955

STUDY OF IGNITION OF GASOLINE BY STATICALLY DETONATED 3.5" HEAT M28A2 ROCKET HEADS (U)

TENTH REPORT ON PROJECT TB3-1224B

ARMOR TEST REPORT AD-1215

DATES OF TEST: 2 December 1954 Through 28 July 1955

OBJECT

To investigate the ignition of gasoline behind various thicknesses of armor plate by 3.5" HEAT, M28A2, rocket heads.

SUMMARY

Thirty-five, 3.5" HEAT, M28A2, rocket heads were detonated against gasoline behind three different thicknesses of armor plate. The frequency of fires for the two thinner armor plates (3/4" and 3") was 100%; for the third and thicker (9") 86%. One round was detonated against gasoline to obtain fastax film data.

CONCLUSION

Gasoline is readily ignited by the 3.5" HEAT, M28A2, rocket head even when it is protected by armor up to nine inches thick.

RECOMMENDATION

An intensive program should be initiated to investigate various means of suppressing fuel fires in armored vehicles subjected to HEAT attack.

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I INTRODUCTION

A. DISCUSSION

1. This test was devised to compare the frequency of ignition of diesel fuel and of gasoline when each fuel was attacked by 3.5" M28A2 HEAT rocket heads. In previous tests the diesel fuel had been attacked under "clean" conditions. Accordingly, the gasoline in this test was attacked under "clean" conditions. A "clean" condition is one in which there is no oil soaked dirt, wood, or other wick-like material in the vicinity of the target fuel can. A wick-like material increases the probability of a fire by increasing the surface area of the fluid so that it is more readily ignited.

2. Four test conditions were initially planned. The variable in these conditions was the thickness of armor plate to be fired through. The four test thicknesses were 3/4", 2", 3.1" and 9.1"; charges were detonated against the thickest and thinnest plates first. This was done to determine whether or not the other two thicknesses need be fired. A very high frequency of fires for both the 3/4" and 9" armor plates was assumed to indicate a similarly high frequency of fire for the intermediate thicknesses.

3. In addition to the above test conditions, Fastax films of a 3.5" HEAT rocket head jet entering and leaving a fuel can were obtained. Representative film strips and a discussion will be found in Appendix D.

II DESCRIPTION OF MATERIEL

A. The gasoline used in this program was winter grade of 85-90 octane rating.

B. The containers for the gasoline were discarded propellant cans, (Box, Steel, MK, No. 16 US Standard gauge, Dwg. No. 76-4-55). The liquid capacity of these cans is approximately 16 gallons. Each can when attacked was 7/8ths full. A total of approximately 540 gallons of gasoline was used.

C. German Tiger tank Hulls and prototype fuel compartments fabricated locally (See fuel compartment drawing in Appendix C), were used as fuel target holders and armor protection.

D. Thirty-five, 3.5" HEAT, M28A2, rocket heads, Lot COP-4-95, were detonated. The heads were boostered with tetryl pellets and initiated electrically by means of Corps of Engineers Special Blasting Caps.

E. Camera-Fastax (10,000 frames/sec).

III DETAILS OF TEST

A. PROCEDURE

1. For this test, five German Tiger Tank Hulls which were fired on in a previous test, but still had enough armor surface for use in this test were available for use as targets. The hulls were especially suited for the test in that no interior components had been installed and the interiors were readily accessible

for the installation and removal of the fuel containers. The hulls also provided armor of 150mm thickness at 50° obliquity. This combination provided an effective thickness of 9.1" when the rocket heads were detonated parallel to the ground.

2. Fuel containers used were discarded propellant cans, which were available in suitable quantity. The containers were filled to 7/8ths capacity and were placed in the hull against the hull side or upper front plate. (See APG Photographs B5603 through B5605, Appendix E.) The containers were held in place by a single back-up plate of 3/8" armor steel and were braced with angle irons or sections of pipe.

3. In the 3" phase of this test, the prototype fuel compartment was used. The front plate of the prototype is 3" thick sloped at 20° from the vertical. For safety reasons, these compartments were placed inside the Tiger Tank Hulls. All rocket heads were detonated with the prototypes in this position. The positioning and bracing of the target fuel cans was the same as in the 9" armor phase. A drawing of the prototype will be found in Appendix C.

4. For the 3/4" armor phase of this test, the side armor of the Tiger Tank Hulls was modified. The modification consisted of a rectangular hole or window cut in the side armor of the tiger tank hull, and angle iron brackets welded at the sides of this window. This makes it easy to use various sizes of armor plate as protection for the fuel cell. So the fuel cell in this phase was sandwiched between a 3/4" face plate and a 3/8" back-up plate. The face plate was wedged in the angle iron brackets with pieces of pipe and other metal objects. The fuel cell and the back-up-plate were braced in the usual manner.

5. The rocket heads were mounted on wooden holders, parallel to the ground, and aimed at the center of the target can. Initiation was accomplished with tetryl pellet boosters and Corps of Engineers Special Blasting caps.

6. The fuel temperatures were measured with a mercury in glass hand thermometer. Ambient temperatures were obtained from meteorological records. These temperatures along with a description of can damage, record of fires, date of fires, and armor thicknesses in each instance are found in table I, Appendix B.

7. Descriptions of the conditions for fastax film data and of the results are found in Appendix D.

B. RESULTS

1. The fire frequency for the 3/4" armor thickness phase was eleven fires in eleven tries. For the 9" armor thickness phase, it was twelve in fourteen. In one case in which fire did not occur, (through the 9" armor) the jet did not exit from the can; and in the other case, ice was found in the can after the rocket head had been fired. One additional rocket head failed to penetrate the 9" armor completely. This charge was discounted as a test round.

2. One of the prototype compartments was liquid tight, and held the gasoline inside after the jet had penetrated and dislodged the target can. All of the fires in this compartment were confined to the compartment. The flames still came through the top grille, however.

3. The other prototype compartment was not liquid tight. Consequently it was engulfed in flames because of the leaking of the gasoline to the floor of the tiger hull.

IV CONCLUSIONS

Gasoline is readily ignited by 3.5" HEAT M28A2 Rocket Heads under the conditions of this test program, that is:

A. In cold weather.

B. Under clean conditions.

C. When protected by steel armor up to 9 inches thick.

V RECOMMENDATION

An intensive program should be initiated to investigate various means of suppressing fuel fires in armored vehicles subjected to ballistic attack.

G. S. BUCZALA
Ordnance Engineer

APPROVED:

BENJAMIN S. GOODWIN
Assistant Director for
Engineering Testing
Dev. & Proof Services

H. L. ROSENBERG
Chief, Terminal
Ballistics Division

APPENDICES

APPENDIX A - Correspondence.

APPENDIX B - Round-By-Round Data - Table I.

APPENDIX C - Drawing: Prototype Fuel Compartment.

APPENDIX D - Fastax Film Data and Discussion.

APPENDIX E - Photographs.

APPENDIX A

Correspondence

CONFIDENTIAL

C O P Y/htl

THRU : Chief, Weapon Systems Laboratory
Director, Development and Proof Services

G.Beichler/ah/24271
16 November 1954

Director, Ballistic Research Laboratories

Vulnerability of Gasoline to the M28A2 3.5 Inch HEAT Round

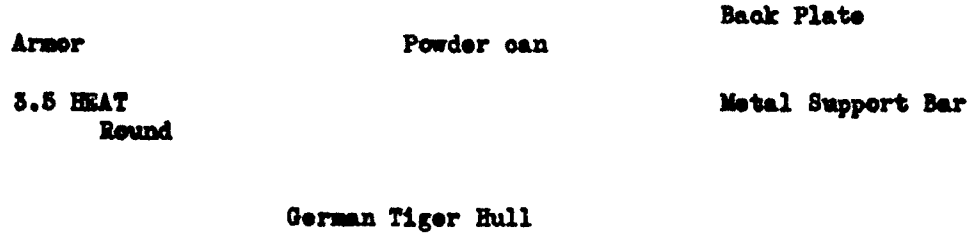
1. There exists in the study of tank vulnerability a necessity to compare the vulnerability of gasoline (80/86 octane) to diesel fuel. To accomplish this a test procedure comparable to that reported in D&PS' forthcoming report, AD 1186, is necessary substituting gasoline in place of diesel fuel. It is desired that the following test be conducted:

a. Attacking Projectile - 3.5 inch M28A2 HEAT projectiles statically fired.

b. Target - 16 gallon gasoline filled powder cans placed behind the armor of clean German Tiger Tanks as shown in Figure 1.

c. Conditions - All rounds are to enter the powder cans at the same fuel level.

Figure 1



2. Table 1 lists the proposed firings:

Table 1

Number of Rounds	Armor Thickness	Obliquity	Location of Round	Fuel Level
10	9.1"	20	Below Fuel Level	7/8 Full
10	3.2"	20	" " "	" "
10	2.0"	0	" " "	" "
10	3/4"	0	" " "	" "

All rounds will be furnished by the Tank Effectiveness Branch, WSL, BRL.

9

SUBJECT: Vulnerability of Gasoline to the M28A2 3.5 Inch HEAT Round
16 November 1954

3. Complete photographic records of the damage after each round plus Fastex moving pictures of a few rounds are desired. Other data of primary interest consist of the classification of fires, i.e.,

a. No fire
b. ground fire
c. small fire
d. ordinary fire

as classified in AD 1188. It is desired that this data along with all other pertinent data on the effectiveness of individual rounds be forwarded to the Tank Vulnerability Section as it is collected.

4. Occasional meetings are desired between DAPS and BRL representatives to discuss problems that arise during the firings. Necessary changes to the firing procedures may be made with the approval of both DAPS and BRL representatives.

5. This program is classified 1A and is to be conducted under Project TB3-1224B, Work Order Number 962-002-00. All data pertaining to the results are to be classified "CONFIDENTIAL".

W. E. RAFERT
Major, Ord Corps
Assistant to Director
Ballistic Research Laboratories

10

APPENDIX B

Round-By-Round Data - Table I

ROUND BY ROUND DATA - 3.5" HEAT vs Gasoline

Date	Armor Thickness (inches)	Temperatures (°F) Air	Fuel	Fire*	Damage to Can
2 Dec	3/4	40	42	3	Top holding by 2 sides. Side seam split, bottom blown off.
3 Dec	3/4	34.2	40	3	Can burning on ground, bottom blown off, side seam split, lid blown off and top - one long seam ripped.
3 Dec	3/4	34.2	39	3	Bottom and top blown off, all seams split.
6 Dec	3/4	29.3	40	3	Top blown off, bottom held on by one edge, side seam split.
6 Dec	3/4	29.3	49	3	Bottom and top blown off, all seams split.
7 Dec	3/4	35	40	3	Bottom was blown off, one long edge on top was split.
7 Dec	3/4	35	38	3	Top blown off, can torn on top edge, and bottom two seams split.
22 Dec	3/4	30.9	30	3	Top and bottom blown off and all seams split.
22 Dec	3/4	30.9	30	3	Bottom holding by edge, side seam split and two edges were split on top end.

* 0 = No Fire.
1 = Small Fire.
2 = Moderate Fire.
3 = Large Fire.

2

Date	Armor Thickness (inches)	Temperatures (°F) Air	Fuel	Fire	Damage to Can
28 Dec	3/4	53	54	S	Top held on by 2 edges, bottom blown off, and side seams split.
28 Dec	3/4	53	55	S	Top held on by one edge, bottom blown off, and side seam split.
2 Dec	9	40	42	S	Jet blew top off, and bottom side seam split.
2 Dec	9	40	42	S	Top blown off, lid out of top, and plug out of bottom.
5 Dec	9	34.2	40	S	Top blown off, and side seam split.
5 Dec	9	34.2	40	0	Can in plate - jet did not exit from can.
6 Dec	9	29.3	31	S	Seam split, top still in place, lid blown out. No sign of jet exit from can.
6 Dec	9	29.3	31	S	Top held on by one edge, bottom held on by 2 edges, and side seam split.
7 Dec	9	35	39	S	Top blown off, and plug blown out of bottom.
7 Dec	9	35	39	S	Jet blew top off, and bottom seam split.

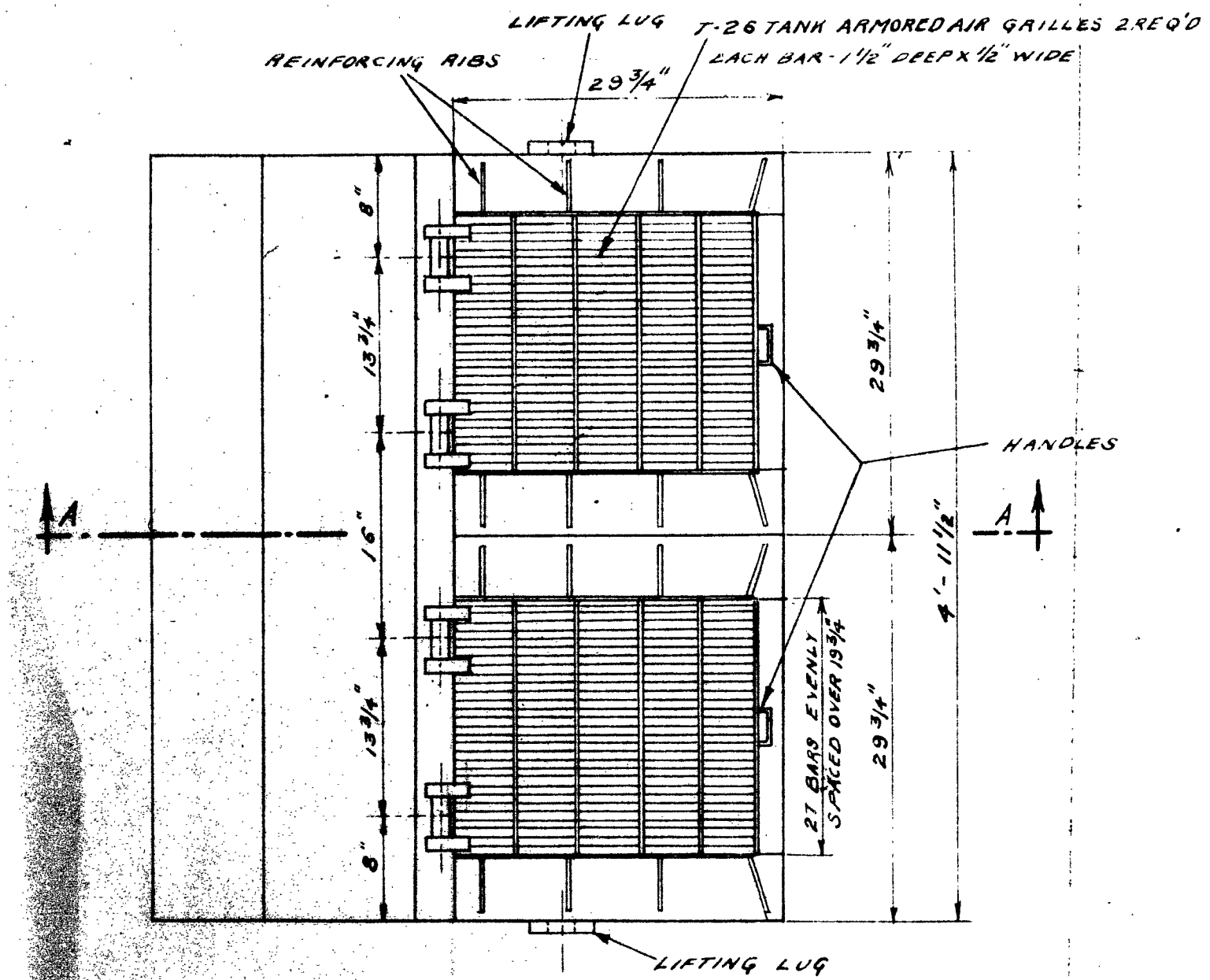
Date	Armor Thickness (inches)	Temperatures (°F) Air	Fuel	Fire	Damage to Can
7 Dec	9	35	39	3	Top blown off, and plug blown out of bottom.
22 Dec	9	30.9	29	3	Top torn on two edges, and bottom torn on two long edges.
22 Dec	9	30.9	30	3	Top blown off, bottom holding on by about 4" of one edge, and side seam split.
22 Dec	9	30.9	30	0	Can out of place, gas on ground, and ice in bottom of can.
28 Dec	9	53	54	3	Top blown off, bottom holding by one side, and side seam split.
28 Dec	9	53	55	3	Top hanging on by one side, lid gone, and bottom blown off.

F

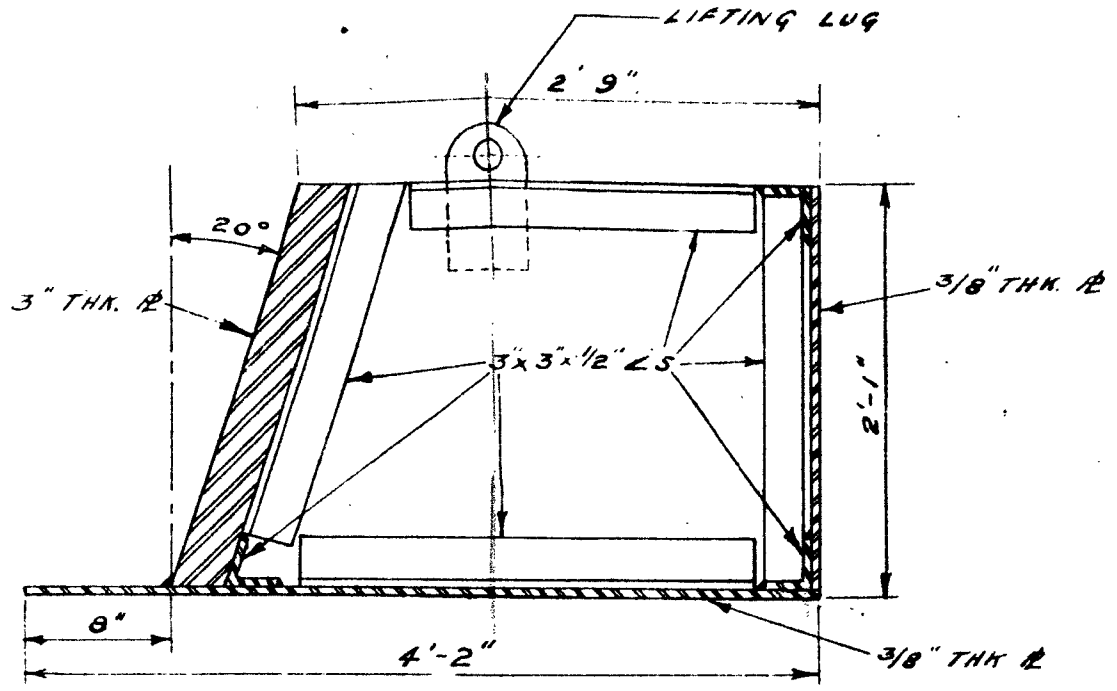
Date	Armor Thickness (inches)	Temperatures (°F) Air	Fuel	Fire	Damage to Can
21 Jan	3	27.5	25	3	Bottom and top blown off, and side seam split.
21 Jan	3	27.5	25	3	Bottom swinging on one edge, and lid was blown off.
24 Jan	3	36	32	3	Bottom and top blown off, and small edge torn by jet and slug.
24 Jan	3	36	32	3	Top blown off, and lid blown off of top.
25 Jan	3	38.2	29	3	Top and bottom blown off, and side seam split.
25 Jan	3	38.2	29	3	Bottom torn on two edges, lid blown out of top, and side seam split.
26 Jan	3	40	35	3	Bottom and top blown off, and side seam split.
26 Jan	3	40	35	3	Top swinging on one edge, and lid blown out of top.
27 Jan	3	24.4	24	3	Top blown off, and side seam split.
27 Jan	3	24.4	24	3	Top blown off, lid out of top, and plug out of bottom.

APPENDIX C

Drawing: Prototype Fuel Compartment



TOP VIEW OF BOX



SECTION "A"-"A"
(SHOWN WITHOUT COVER)

NOTES: BOX IS OF ALL WELDED CONSTRUCTION
ALL PLATE IS ROLLED HOMOGENEOUS ARMOR

PROTOTYPE TANK
FUEL COMPARTMENT
SCALE 3/32"=1"

DRAWN AT APG	DRAWN BY W. SEWING
D&PS	DATE: 7 APRIL 1954
A&A DIVISION	CHECKED BY J HANNA
ARMOR BRANCH	DATE: 7 APRIL 1954

APPENDIX D

Fastax Film Data and Discussion

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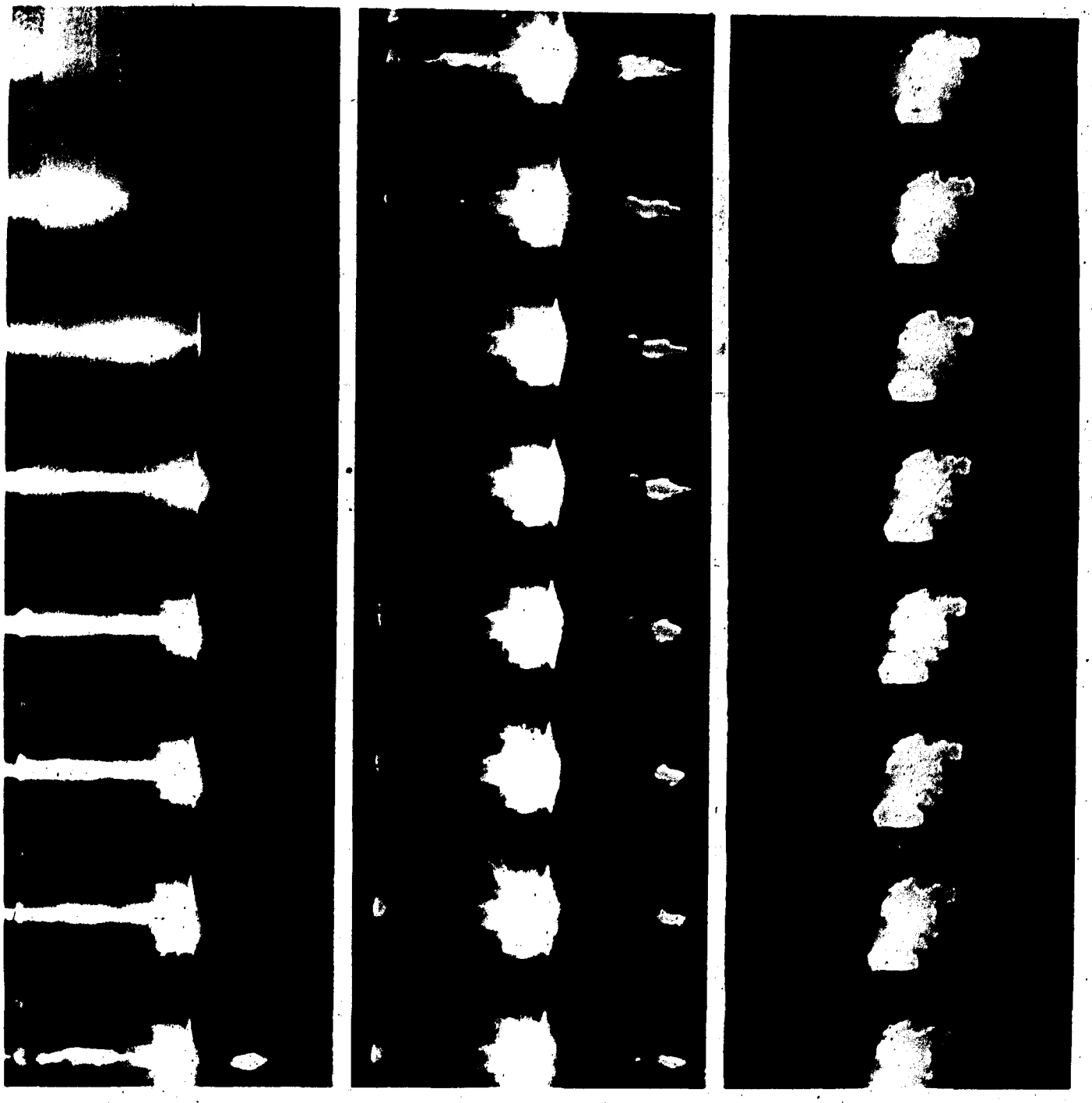
FASTEX FILM DATA AND DISCUSSION

3.5" HEAT Rocket Head vs Gasoline

The rocket head was aimed parallel to the ground at an unprotected fuel container some 15 feet away. The fuel container was placed on top of a 50 gal. drum and a 3" piece of armor plate. This arrangement brought the center of the container just even with the rocket head position. Ten feet behind the fuel container a white backdrop of celotex was nailed to stakes in the ground. The camera was placed 35 feet from the side opposite the white celotex backdrop. It was synchronized to start by the same electric impulse that detonated the rocket head.

The rocket head was detonated from the inside of a nearby Tiger tank hull. This was done to protect the camera and other equipment from rocket head fragments.

APG Photograph B10140 is the positive print of a 3 strip portion of the Fastax film. The jet of the shaped charge was traveling at approximately 17000 ft/sec. The can with fluid inside slowed the jet to 5000 ft/sec. A large flash on the front of the fuel container resulted when the jet hit the container. This flash continued for quite a length of time (about .0065 sec) until masked by the burning gasoline vapors and fluid that exited through the jet entrance hole. The container began to bulge as the jet exited from the container. This bulging continued and reached its maximum in about 5.6 milliseconds. The relaxing of this bulge coincided with a loss of liquid and vapor through the entrance and exit holes. Fire resulted on the front of the can. In the final strip of film (APG Photo B10140) the fuel container is enveloped by fire (flame or flash) from the front and by smoke from the rear. For a comparison with similar photographs of 3.5" HEAT against diesel fuel, and water, see APG Report AD-1188, Photographs A92195 and A92192.



Project No. TB3-1224B. Rocket Heads, 3.5", HEAT, versus Gasoline. Round One. Positive prints of high speed motion picture strips (10 frames - 1 millisecond). Container 15' from armor and HEAT Round. LEFT: Note flash of impacting jet in fourth frame, exit of jet along with flash in bottom frame. CENTER: Flashing continues in top two frames, target can begins to bulge in bottom frames. RIGHT: This strip shows beginning of fire on front side of can.

APPENDIX E

Photographs: APG Numbers B5603 - B5606 (inc.)

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B5603 CONFIDENTIAL ABERDEEN PROVING GROUND 10 January 1955

Project No. TB3-1224B. Vulnerability of Gasoline to 3.5" HEAT. Frontal slope, No. 3 tiger hull, showing round-in-place on wooden frame. Tip of gasoline can showing through machine gun port. Gasoline can behind 9" of plate at obliquity used.

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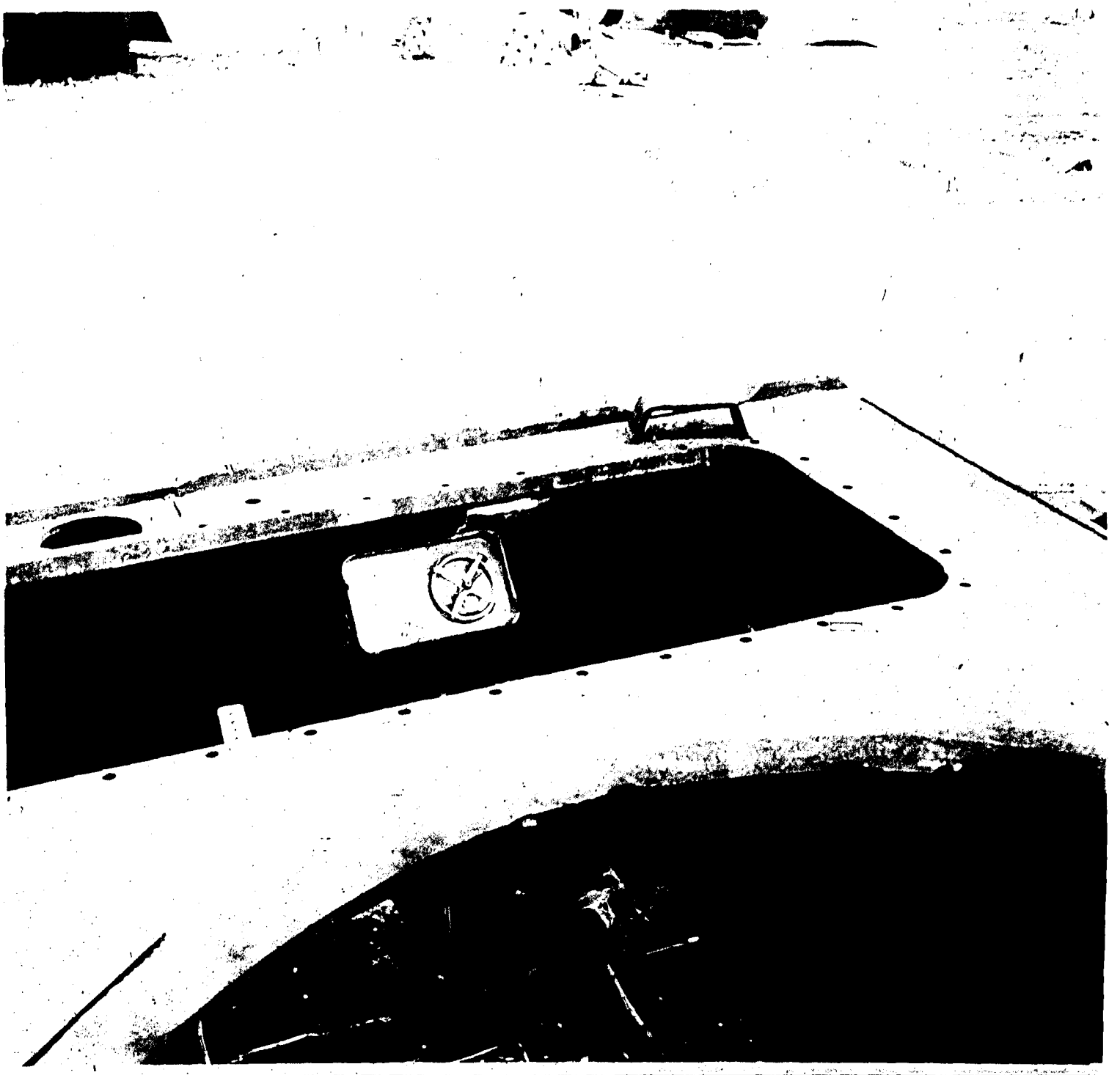

B5604 CONFIDENTIAL ABERDEEN PROVING GROUND 10 January 1955

Project No. TB3-1224B. Vulnerability of Gasoline to 3.5" HEAT.
Inside back of frontal slope of No. 3 tiger hull, showing gasoline can held in place by back-up plate and pipe braces. The can is a used 105 lb. powder can.

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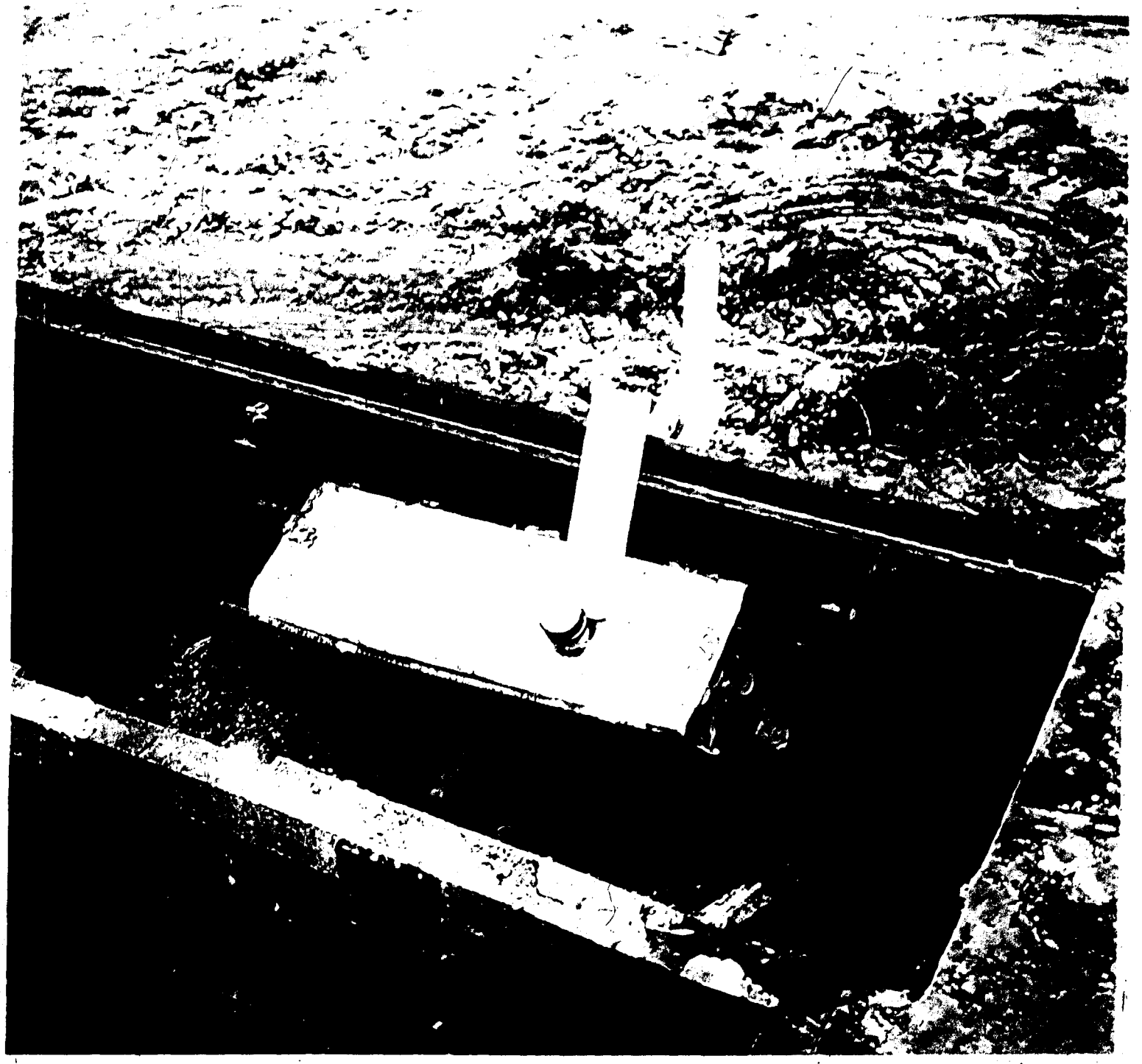

B5605 CONFIDENTIAL § ABERDEEN PROVING GROUND § 10 January 1955

Project No. TB3-1224B. Vulnerability of Gasoline to 3.5" HEAT. Back of left side of No. 2 tiger hull showing gasoline can in place behind 3/4" plate. NOTE: Brackets on ends of can are used to hold various sizes of armor plate.

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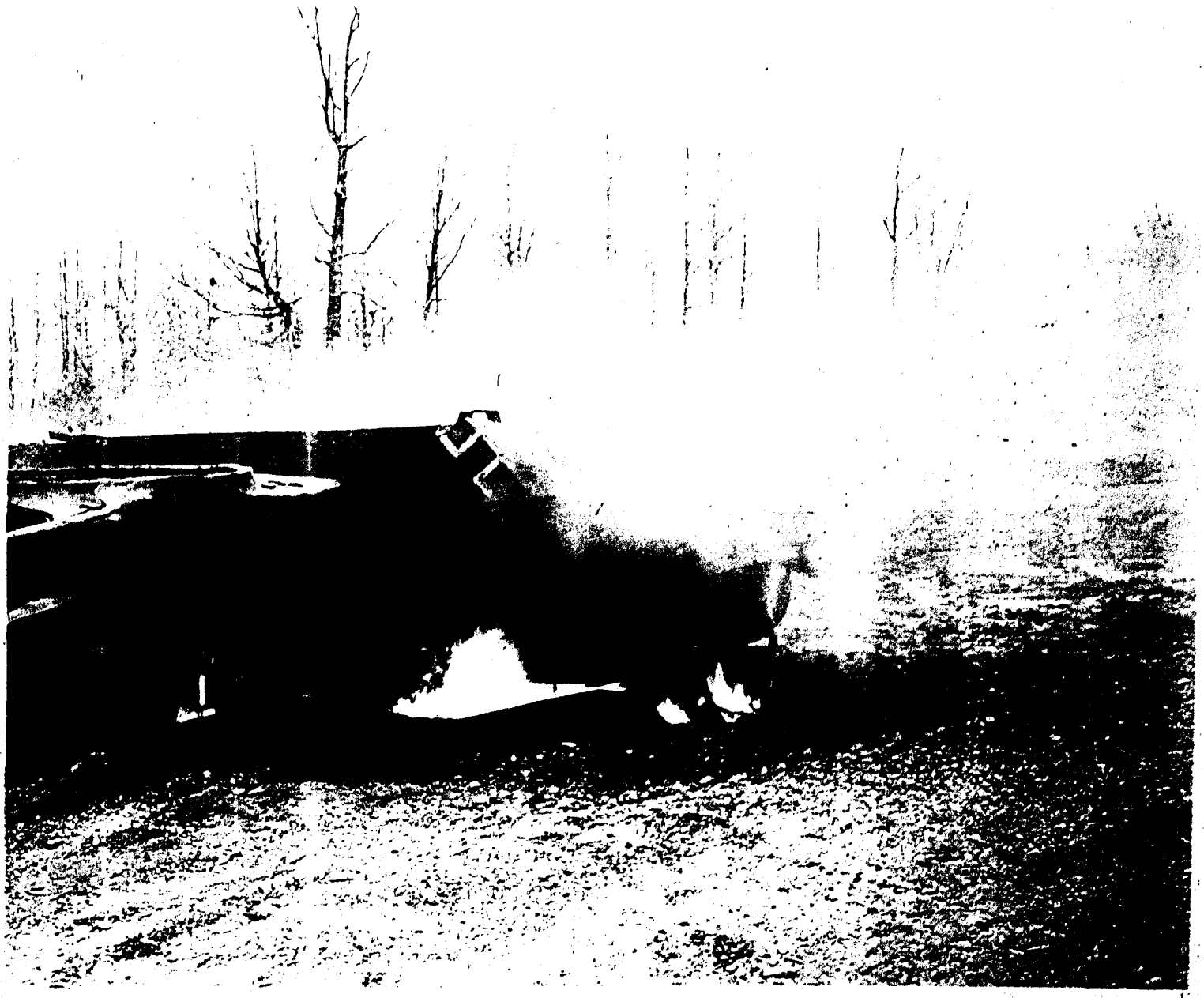

B5606 CONFIDENTIAL ABERDEEN PROVING GROUND 10 January 1955

Project No. TB3-1224B. Vulnerability of Gasoline to 3.5" HEAT.
Picture shows fire in No. 3 tiger hull. Fire in and under hull.
Photograph was taken about 10 minutes after fire started.